FINAL REPORT

BIOLOGICAL EFFECTS OF ULTRAVIOLET RADIATION ON PLANT GROWTH AND DEVELOPMENT IN FLORIST AND NURSERY CROPS

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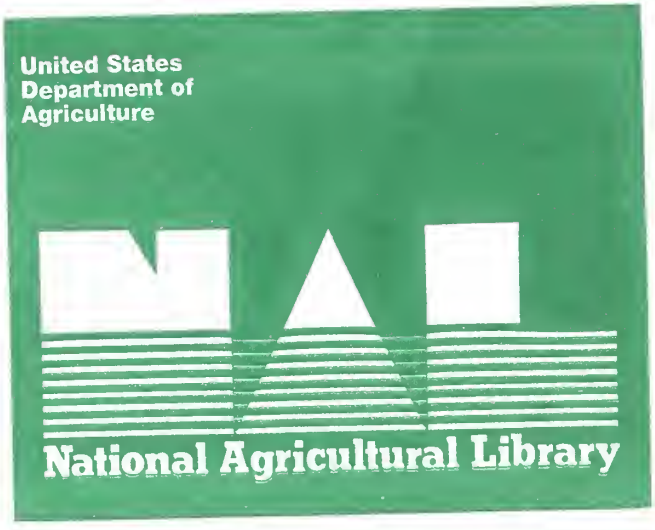
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Biological Effects of Ultraviolet Radiation on Plant Growth and Development in Florist and Nursery Crops

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Abstract. Under simulated UV-B enhancement conditions, florist and nursery plants were irradiated in a glass greenhouse using Westinghouse FS-40[2/] fluorescent sunlamps filtered with 5 mil cellulose acetate filters for 6 hours (10:00 a.m.-4:00 p.m.) each day for 2-12 weeks. A simulated sun curve and a computer-generated action spectrum were used to determine biologically effective dosage to provide a wide range of UV-B irradiances from 50-400% increase in biologically effective UV (4-13 weighted mWm^{-2}). Visible injury was noted in only 8 of 74 florist and nursery species. Leaves of 'C-I-White' and 'C-I-Red' poinsettia showed distortion, glazing and abnormal leaf curvature. Of all 16 Coleus cultivars, 'Glory of Luxemburg' was the most sensitive and 'Pineapple' the most resistant to 50% or greater increase in biologically effective UV exposure for 2 weeks. Breakdown in anthocyanin content was observed in 15 of the 16 cultivars, with leaf extracts and fresh leaves of 'Red Rainbow' showing a large increase in absorbance at 285 nm. Aster, Hollyhock, Impatiens and Vinca plants irradiated for 4 weeks developed slight chlorosis (degradation of chlorophyll). Stress response was noted in all 6 Browallia species and cultivars. None of the 12 shrub or 6 tree species irradiated showed any sign of stress response to 12 weeks of UV-B.

1/ Research Horticulturist, Florist and Nursery Crops Laboratory, Plant Genetics and Germplasm Institute.

2/ Mention of a trademark name, proprietary product or vendor does not constitute a guarantee or warranty of the product by the U. S. Department of Agriculture and does not imply its approval to the exclusion of other products or vendors that may also be suitable.

Biological effects of UV-A (320-400 nm) and UV-C (less than 280 nm) radiation in plants are well documented (2, 5, 6). A great variety of physiological and morphological plant responses to UV radiation has been demonstrated over the past 75 years. However, most of these experiments have employed ultraviolet lamps which emit radiation unlike the radiation present in the normal terrestrial solar spectrum (3, 4).

The effects of UV-B (280-320 nm) radiation on man have been studied extensively but relatively little is known of the effects of UV-B radiation on growth and development of plants (1, 2, 6). The impact of low levels of UV-B radiation on plant growth and development is largely unknown since most UV-B studies were conducted with lamps that emitted both UV-B and UV-C.

Previous biological studies in the UV-B region were greatly limited by a lack of suitable monitoring equipment and inadequate narrow and broadband radiation sources. Under the auspices of the Environmental Protection Agency (EPA) interagency program on Biological and Climatic Effects Research (BACER), the USDA Agricultural Equipment Laboratory (8) and the Instrumentation Research Laboratory of Beltsville developed improved experimental facilities for irradiating, measuring and monitoring UV-B radiation. My objective was to identify, through a screening program, species and cultivars of economically important florist and nursery plants that are sensitive or resistant to UV-B radiation under glass greenhouse conditions, utilizing standardized techniques and improved instrumentation.

Observations were made on the extent of visual injury, change in pigmentation, leaf abscission, glazing, bronzing, chlorosis and other plant stress responses.

Materials and Methods

Experimental facilities for UV-B irradiation were developed in cooperation with the Beltsville Agricultural Equipment Laboratory and the Instrumentation Research Laboratory. The former developed the lamp configuration, weighting functions and irradiance levels at selected locations; the latter developed the instrumentation (spectroradiometer) for measuring and monitoring UV-B radiation.

Westinghouse FS-40 fluorescent sunlamps were used in conjunction with appropriate plastic filters to provide increased levels of UV-B irradiation. Under simulated UV-B enhancement conditions, florist and nursery plants were irradiated in the greenhouse under 5 mil cellulose acetate (UV-A & B) or 5 mil Mylar (UV-A only) for 6 hours continuously each day for 2-12 weeks about solar noon (10:00 a.m.-4:00 p.m.). Minimum night temperature was kept about 17^{o} C and day temperatures did not exceed 24^{o}.

The standard protocol established was for FS-40 sunlamps to be aged 100 hours before use; cellulose acetate (CA) filters presolarized for 6 hours; filters changed twice weekly; and lamp height adjusted with each filter change to maintain UV levels. Plants were irradiated under 4 fixtures, each containing 2 FS-40 sunlamps spaced 30 cm apart and 82 cm above plants. A simulated sun curve and a computer-generated action spectrum were used to determine biologically effective UV-B dosage. Experimental plants were placed in selected locations to provide a wide range of UV-B irradiances from 50-400% increase in biologically effective UV (4-13 weighted mWm^{-2}). Irradiance levels were verified at the beginning and end of experiments by measuring with an Optronic Laboratories Inc., Model 725 UV-B Radiometer[2/].

Results and Discussion

A list of plants tested for the relative sensitivity or resistance to enhanced UV-B radiation in glass greenhouse is shown in Table 1. Visible injury was noted in only 8 of 74 florist and nursery species (Table 2). The remaining 66 species examined were found to tolerate an increase in biologically effective levels of UV from 50-400%. The most common plant response to high levels of UV-B irradiation (100% or greater increase in biologically effective UV under FS-40 sunlamps filtered with 5 mil CA) was breakdown of anthocyanins and chlorophyll, or more commonly, a glazing and bronzing of the tissue which is generally attributed to the presence of oxidized, polymerized, phenolic compounds. This bronzing or darkening phenomenon serves as a convenient indicator of UV absorption and damage. Visible lesions, loss of chlorophyll and reduction or increase in pigmentation were not immediate but rather appeared slowly as reflections of disturbance in the basic metabolic process. The stress responses did not develop until 3-4 days after beginning UV exposure.

'C-I-White' and 'C-I-Red' poinsettia plants were particularly sensitive to UV-B radiation and showed glazing, distortion and abnormal leaf curvature that increased in severity with increased UV-B levels. Under high levels of UV-B irradiation (100% or greater increase in biologically effective UV), leaves of 'Supreme Annette Hegg' poinsettia formed purplish- red anthocyanins, a typical stress response. It is possible that 'Supreme Annette Hegg' has the capacity to prevent damage to sensitive tissue from UV-B radiation by producing materials in epidermal cells that absorb the radiation. Flavonoids have been shown to absorb effectively in the UV-B

radiation region (7). Since anthocyanins were identified in the epidermal cells of poinsettias, it seems likely that these compounds serve to protect the inner cells of the leaves against further ultraviolet damage.

'Pineapple' was the only one of 16 Coleus cultivars that showed no visible pigment changes when exposed to artificially enhanced UV-B irradiation.

Of the 16 cultivars, 'Glory of Luxemburg' was the most sensitive. It was the only one that showed a slight loss of anthocyanin pigmentation at 50% increase in biologically effective UV.

The remaining 14 cultivars of Coleus required at least 100% increase in biologically effective UV before showing visible pigment breakdown.

Exposure of Coleus blumei 'Red Rainbow' for 2 weeks to enhanced UV-B radiation at ca 100% in biologically effective UV produced no significant effect on dry matter accumulation, fresh weight, leaf area, or plant height; however, the red pigment in young leaves was greatly reduced. A small change in degradation of the anthocyanin pigment was evident after 6 hours of exposure. This change was intensified with increased exposure up to 24 hours (4-6 hr UV-B radiation). Both leaf extracts and fresh leaves showed a large increase in absorbance at 285 nm.

Visible breakdown in anthocyanin content was also observed in 13 of the other 14 cultivars exposed to 50% or greater increase in biologically effective UV for 2 weeks. This decrease in the anthocyanin content of Coleus leaves suggests the usefulness of these plants as indicators of UV-B damage.

Aster, Hollyhock, Impatiens and Vinca plants irradiated for 4 weeks showed only a subtle UV stress response that was characterized by chlorosis (degradation of chlorophyll). The injurious effects of UV-B radiation were soon masked by the growth of new leaves which emerged from the terminal and lateral buds following the cessation of UV exposure. The length of time necessary for this regrowth was dependent upon the degree of injury.

Fatsia japonica was the only one of the 19 tender perennial species in which plant growth was slightly inhibited by 100% or greater biologically effective UV. None of the 12 shrubs or 6 tree species irradiated showed any sign of stress response to ultraviolet radiation after 12 weeks of exposure.

Stress response to enhanced UV-B was noted in all 6 Browallia species and cultivars after 4 weeks of irradiation. Leaves of Browallia 'Vanja', 'Ultra', 'Panama', 'Blue Bells Improved', and 'Blue Troll' were smaller, twisted and distorted. The only sign of stress in Browallia viscosa 'Sapphire' was the formation of purplish pigment in normally young green flower buds.

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Table 1. Relative sensitivity and type of injury of selected species and cultivars of florist and nursery plants in response to enhanced UV-B irradiance.

Common Name and Cultivar	Genus and Species	Type of Plant[1/]	UV-B Sensitivity[2/]	Type of Injury[3/]
African Violet	Saintpaulia ionantha Wendl.			
Blue Fairy Tale		TP	IS	
Ballet		TP	IS	
Ageratum	Ageratum houstonianum Mill.			
Biscaya		A	IS	
North Star		A	IS	
Blue Blazer		A	IS	
Atlantic		A	IS	
Aglaonema	Aglaonema commutatum Schott	TP	IS	
Althaea	Hibiscus syriacus L.	A	IS	
Alyssum	Lobularia maritima (L.) Desv.			
Carpet of Snow		A	IS	
Amaranthus	Amaranthus tricolor L.			
Molten Fire		A	IS	
Red Leaf		A	IS	
Aphelandra	Aphelandra squarrosa Nees	TP	IS	
Aster	Aster alpinus L.			
Totem Pole		A	S-1	C

Common Name and Cultivar	Genus and Species	Type of Plant[1/]	UV-B Sensitivity[2/]	Type of Injury[3/]
Arborvitae	Thuja occidentalis L.			
Globosa		S	IS	
Pensa		S	IS	
Pyramide		S	IS	
Rheindiana		S	IS	
Balsam Fir	Abies balsamea (L.) Mill.	T	IS	
Basil Red Leaf	Ocimum basilicum L.	TP	IS	
Begonia, tuberous rooted	Begonia x tuberhybrida Voss	TP	IS	
double-mix		TP	IS	
Begonia Roulette	Begonia rex Putz.	TP	IS	
Browallia	Browallia viscosa HBK			
Sapphire		A	S-1	PE
Browallia	Browallia speciosa Hook.			
Blue Bells		TP	S-1	D, T
Blue Troll		TP	S-1	D, T
Ultra		TP	S-1	D, T
Vanja		TP	S-1	D, T
Panama		TP	S-1	D, T
Boxwood	Buxus microphylla Siebold & Zucc.			
Jap. Green Beauty		S	IS	
Mic. Green Velvet		S	IS	

Common Name and Cultivar	Genus and Species	Type of Plant[1/]	UV-B Sensitivity[2/]	Type of Injury[3/]
Caladium candidum	Caladium x hortulanum Birdsey	TP	IS	
Calendula Fiesta	Calendula officinalis L.	A	IS	
Camellia sasanqua	Camellia sasanqua Thunb.	S	IS	
Showa		S	IS	
Camellia Showa	Camellia japonica L.	S	IS	
Canna Ambassador	Canna x generalis L. H. Bailey	TP	IS	
Chinese Chestnut	Castanea mollissima Blume	T	IS	
Christmas Pepper	Capsicum annuum L.	A	IS	
Chrysanthemum	Chrysanthemum morifolium Ramat.	P	IS	
Classic		P	IS	
Elegant		P	IS	
Fred Shoesmith		P	IS	
Flaming Sun		P	IS	
Goldtone		P	IS	
Iceberg		P	IS	
Imp. Ind. White		P	IS	
Jackpot		P	IS	
Minn. Autumn		P	IS	
Pancho		P	IS	
Penguin		P	IS	

Common Name and Cultivar	Genus and Species	Type of Plant[1/]	UV-B Sensitivity[2/]	Type of Injury[3/]
Shoesmith		P	IS	
Sunburst		P	IS	
Superchief		P	IS	
Tinkerbell		P	IS	
Coleus	Coleus blumei Benth.			
Pink Rainbow		A	S-1	PL, D, T
Red Rainbow		A	S-1	PL, D, T
Aetna		A	S-1	PL, D
Campfire		A	S-1	PL, D
Carefree Red		A	S-1	PL, D
Freckles		A	S-1	PL, D
Fredericci		A	S-1	PL, D
Glory of Luxemburg		A	S-2	PL, D
Harlequin		A	S-1	PL, D
Marty		A	S-1	PL, D
Pineapple		A	IS	
Saber Jade		A	S-1	PL, D
Saber Golden		A	S-1	PL, D
Saber Pink Dragon		A	S-1	PL, D
Saber Velvet		A	S-1	PL, D
Saber Jade Pastel		A	S-1	PL, D
Col. Blue Spruce	Picea pungens Engelm.	T	IS	
Cone Flower	Rudbeckia hirta L.	A	IS	

Common Name and Cultivar	Genus and Species	Type of Plant[1/]	UV-B Sensitivity[2/]	Type of Injury[3/]
Crape Myrtle	Lagerstroemia indica L.	S	IS	
Dusty Miller	Centaurea maritima Dufour	A	IS	
Exacum Affine	Exacum affine Balf. f.			
Richly Frag.		A	IS	
Blythe Spirit		A	IS	
Midget		A	IS	
False Aralia	Dizygotheca elegantissima (Hort. Veitch) R. Vig. & Guillaum.	TP	IS	
False Cypress	Chamaecyparis pisifera (Siebold & Zucc.) Endl. 'Cyanoviridis'	S	IS	
Fatsia	Fatsia japonica (Thunb.) Decne. & Planch.	TP	S-1	G
Geranium	Pelargonium x hortorum L. H. Bailey			
Carefree White		A	IS	
Scarlet Sprinter		A	IS	
Glory Bush	Tibouchina urvilleana (DC.) Cogn.	TP	IS	
Glory Lilly	Gloriosa rothschildiana O'Brien	TP	IS	
Gloxinia Emperor Wilhelm	Sinningia speciosa (Lodd.) Hiern	TP	IS	
Hens & Chickens	Sempervivum tectorum L.	P	IS	

Common Name and Cultivar	Genus and Species	Type of Plant[1/]	UV-B Sensitivity[2/]	Type of Injury[3/]
Heliotrope Marine	Valeriana officinalis L.	P	IS	
Holly	Ilex crenata Thunb.			
Glory		S	IS	
Golden Gem		S	IS	
Hollyhock	Alcea rosea L.	A	IS	
Majorette		A	IS	
Powderpuffs		A	S-1	C
Impatiens	Impatiens wallerana Hook. f.			
Aflame		A	IS	
Aloha		A	IS	
Futura Coral		A	IS	
Futura Pink		A	IS	
Futura Red		A	IS	
Futura White		A	IS	
HUC		A	IS	
White Imp		P	S-1	C
Juniper	Juniperus chinensis L.			
Glanca		S	IS	
Gold		S	IS	
Old Gold		S	IS	
Pftizer		S	IS	
Skyrocket		S	IS	

Common Name and Cultivar	Genus and Species	Type of Plant[1/]	UV-B Sensitivity[2/]	Type of Injury[3/]
Lantana	Lantana montevidensis (K. Spreng.) Briq.	TP	IS	
Larkspur Dk. Blue Supreme	Delphinium exaltatum Ait.	A	IS	
Leucothoe	Leucothoe axillaris (Lam.) D. Don	S	IS	
Marigold Bolero	Tagetes patula L.	A	IS	
Cracker Jack	Tagetes erecta L.	A	IS	
Dwarf French Dlb.	Tagetes patula L.	A	IS	
Early Gigantic	Tagetes erecta L.	A	IS	
First Lady	Tagetes erecta L.	A	IS	
Gold Rush	Tagetes erecta L.	A	IS	
Hawaii	Tagetes erecta L.	A	IS	
Honeybee	Tagetes patula L.	A	IS	
Orange Sherbet	Tagetes patula L.	A	IS	
Petite Gold	Tagetes patula L.	A	IS	
Petite Yellow	Tagetes patula L.	A	IS	
Spun Gold	Tagetes patula L.	A	IS	
Norway Spruce	Picea albies (L.) Karst.	T	IS	
Pansy Goldsmith Grant	Viola x wittrockiana Gams	A	IS	
Peperomia	Peperomia obtusifolia (L.) A. Dietr.	TP	IS	
Periwinkle	Vinca minor L.	P	S-1	C

Common Name and Cultivar	Genus and Species	Type of Plant[1/]	UV-B Sensitivity[2/]	Type of Injury[3/]
Petunia	Petunia x hybrida Vilm.			
All Star		A	IS	
Commanche		A	IS	
Pink Cascade		A	IS	
Pink Magic		A	IS	
Plum Pink		A	IS	
Silver Magic		A	IS	
Sugar Daddy		A	IS	
Sugar Plum		A	IS	
Pieris	Pieris japonica (Thunb.) D. Don ex G. Don	S	IS	
Plantain Lily	Hosta sieboldii (Paxt.) J. Ingram	P	IS	
Poinsettia	Euphorbia pulcherrima Willd ex Klotzsch			
Annette Hegg		TP	IS	
C-I-Red		TP	S-2	D, G
C-I-White		TP	S-2	D, G
Prof. Laurie		TP	IS	
Super Star		TP	IS	
Supreme Annette Hegg		TP	S-1	PE
V-10 (Amy)		TP	IS	
White Annette Hegg		TP	IS	

Common Name and Cultivar	Genus and Species	Type of Plant[1/]	UV-B Sensitivity[2/]	Type of Injury[3/]
Portulaca, yellow	Portulaca grandiflora Hook.	A	IS	
Primrose	Primula obconica Hance	P	IS	
Red Improved Rose	Rosa x hybrida	S	IS	
Red Scarlet Maple	Acer rubrum L.	T	IS	
Rex Begonia	Begonia x rex-cultorum L. H. Bailey	TP	IS	
Salpiglossis Emperor	Salpiglossis sinuata Ruiz & Pav.	A	IS	
Salvia	Salvia splendens Sello ex R. & S.			
Rodeo		A	IS	
St. John's Fire		A	IS	
Schefflera compacta	Brassaia actinophylla Endl.	TP	IS	
Snapdragon	Antirrhinum majus L.			
Biocolor Majus Tet		A	IS	
Potomac White		A	IS	
Rocket White		A	IS	
Rose Pixie		A	IS	
Spider Flower	Cleome speciosa Raf.	A	IS	
Stokes Aster	Stokesia laevis (J. Hill) Greene	P	IS	
Taxus	Taxus cuspidata Siebold & Zucc.	S	IS	
Densa		S	IS	

Common Name and Cultivar	Genus and Species	Type of Plant[1/]	UV-B Sensitivity[2/]	Type of Injury[3/]
Intermedia		S	IS	
Media Brownii		S	IS	
Media Kelsey		S	IS	
Torenia	Torenia fournieri Linden ex E. Fowin.	A	IS	
Verbena Springtime	Verbena x hybrida Voss	A	IS	
Veronica	Hebe buxifolia (Benth.) Cockayne & Allan	P	IS	
Vinca Trailing Variegata	Vinca major L.	P	IS	
Zinnia	Zinnia elegans Jacq.			
Carved Ivory		A	IS	
Goddess		A	IS	
Isabelina		A	IS	
Peter Pan Pink		A	IS	
White Dogwood	Cornus florida L.	T	IS	

1/ A = annual; P = perennial; TP = tender perennial; S = shrub; T = tree.

2/ As indicated by plant expression: S = sensitive to either 100% (S-1) or 50% (S-2) increase in biologically effective UV; IS = insensitive.

3/ Visual injury to leaf: C = chlorosis; D = distortion; G = glazing; PL = pigment loss; PE = pigment enhancement; T = twisted.

Table 2. Relative sensitivity of 74 species of florist and nursery plants in response to enhanced UV-B irradiance.

	Annuals	Perennials	Shrubs	Trees
Number Irradiated	27[1/]	29[1/]	12	6
Sensitive Plants	Asters - S-1	Impatiens - S-1	None	None
	Browallia - S-1	Poinsettia - S-1, 2		
	Coleus - S-1, 2	Fatsia - S-1		
	Hollyhock - S-1	Vinca - S-1		

1/ S-1 = Sensitive to 100% or greater increase in biologically effective UV.

S-2 = Sensitive to 50% or greater increase in biologically effective UV.